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Papilloma of the Skin Occurring in an Electric Eel, *Electrophorus electricus* (Linnaeus).

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(Plates I-VI).

With the increase in the reported instances of abnormal growths occurring in fishes, it has become apparent that cutaneous tumors of teleosts are more frequently encountered than are the visceral neoplasms affecting deeper-lying organs. Among the skin tumors of fishes those arising in the connective tissue of the derma or corium seem to be more common than those growths composed of the squamous and mucus cells of the epidermis. There are, finally, a group of papillary tumors of the skin in which the hyperplastic epithelium is heavily supported by a stroma of connective tissue carrying blood and lymphatic vessels and occasionally nerves to the tumor. These growths represent both an epithelial and mesodermal response with both types of cells about equally distributed. Such tumors may be classified as fibro-epithelial growths of the skin. Unlike neoplastic growths in mammals, teleost tumors which are composed principally of epidermal cells appear to be exceedingly rare. Even when they occur in a malignant form (epithelioma), their rate of growth is a relatively slow one, and the tumor, although involving adjacent tissues, usually remains localized in the region where it has its origin, rarely giving rise to the secondary growths in distant tissues or organs so frequently found in mammalian and avian tumors.

Of the few benign epithelial tumors in fishes which have been reported in the literature, the following instance described by Takahashi (1929) may be mentioned as an example. The growth was 3 x 2 x 0.5 cm., grayish-white in color, and occurred in a Crucian carp, *Carassius carassius*, occupying the region of the left operculum. It was sharply circumscribed and showed on its surface dilated blood vessels. The tumor was composed histologically of epidermal cells which were flattened near the surface and exhibited some cornification. Along the deep surface of the tumor there was an active proliferation of epithelial cells into the derma. Interstitial connective tissue

was scanty but fairly well supplied with blood vessels. There was no necrosis, nor were there metastases. Attempts to transplant small pieces of tissue into other fishes of the same species were unsuccessful.

There are no tumors reported up to the present time occurring in the electric eel, *Electrophorus electricus* (Linnaeus). The small cutaneous growth here described developed in the right mid-dorsal region of a large adult electric eel, caught in the Amazon river basin and maintained in good health in a fresh water tank at the New York Aquarium for a period of more than four years. This particular eel, measuring 6 feet in length and 18 inches in largest circumference, had been tested frequently for electrical discharges estimated by measurement to be approximately 350 volts and 40 watts (Coates, Cox & Granath, 1937). Such electrical discharges were repeated at intervals of about 2/1,000 of a second when the eel was disturbed. Other eels subjected to the treatment in measuring electrical discharges for approximately the same period showed no similar growths. The growth began as a small elevation of the skin, pinkish-gray in color, and a few millimeters in diameter. Its maximum growth of 2 x 2.5 cm. was reached in about ten weeks, at which time it was excised for purposes of histological study. No recurrence took place during the remaining year and a half of life.

The growth was a grape-like pedunculated mass (Plate I, Figs. 1 and 2) and was attached to the skin by a narrow short stalk above the lateral line. It did not appear to have its origin in the skin overlying the usual distribution of the electric organs. It was of considerable interest, therefore, when the microscopic study disclosed evidences of nerve trunks and nerve terminations in the epithelium of the growth itself (Plates, IV & V, Figs. 7 and 10).

The epithelial tumor, regarded as a benign papilloma, was composed of solid masses of squamous epithelium commingled with very numerous mucous cells, in an arrangement far more irregular than that exhibited by the normal skin (Plate II, Figs. 3 and 4). The epithelium composing the various lobes of the grape-like mass was supported by a central narrow fibrous core of connective tissue containing many small blood vessels along the course of which existed dendritic melanophores. The linear distribution of pigmented cells external to the thin walls of blood vessels gave to the interior of the tumor the peculiar branching or tree-like effect seen by transillumination in the gross specimen cleared in cedar oil (Plate I, Fig. 2). It will be noted that pigmented lines identifying the various ramifications of the connective tissue stroma extended outward nearly to the free surface of the growth.

It is not the purpose of the present paper to refer in detail to the rather complicated structure of the skin of the electric eel. It may be stated briefly, that the normal epidermis (Plate VI, Figs. 11 and 12) approximately 20-30 cells in depth, rests upon a well developed basement membrane which in its turn separates epithelium (E) from the corium (C). The latter is composed of dense connective tissue fibers supporting the blood capillaries, lymphatic vessels, small nerve trunks and branches and numerous melanophores. The pigment cells are spread out in horizontal arrangement, at times in several layers, immediately below the hyaline basement membrane. In the normal skin, extending outward at right angles to the surface of the body, are found at short regular intervals numerous prolongations of the fibrous tissue of the corium, passing as supporting septa (T) outward into the epithelium (Plate VI, Fig. 11). These supporting septa of connective tissue are somewhat conical in shape with the broader base continuous with the corium while externally they taper off to form finely pointed or club-shaped tips of delicate connective tissue which in this way carry the terminal branches of blood capillaries with closely lying melanophores to points near the extreme outer limits of the epithelial surface. Such sup-

porting septal strands, single or branching, form a region of attachment for narrow elongated closely packed palisade-like epithelial cells (T) (Plate VI, Fig. 12). In contrast with these the epidermal cells springing from the basement membrane between the supporting septa form a system of low cuboidal and small round epithelial cells several layers in density which in all probability represent matrix cells that give rise to predominant squamous and mucous cells of the many-layered epidermis. Relatively few elongated or fusiform cells are found resting on the basement membrane between septa.

Since both the above-mentioned prolongations of connective tissue from the basement membrane and the tuft-like arrangement of narrow epithelial cells covering their tips are very conspicuous features in the skin of the electric eel, it seems rather reasonable to suppose that they are somehow involved in the conduction of the electric discharge from the tissue of the fish into the surrounding water. If these structures differ in electric conductivity from the surrounding epithelial tissue, their presence must modify the distribution of electric current through the epithelium. If they are markedly more conducting than the surrounding tissue, their effect will be to concentrate the current in their own structure through the layers of cells near the basement membrane. The branching of the prolongations near the outer boundary of the epithelium would diffuse the current again where it passes through the outer layers. If such a distribution of current in the epithelium exists, its advantage may be to by-pass the discharge around the matrix cells and so to confine any injurious effect it may have on the epithelial tissue to the outer layers of cells which are constantly replenished.

In our preparations, the extreme outer layer of cells of the normal epidermis in contact with aquatic environment is composed of mucous cells.

In the papillomatous growth all forms and shapes of epithelial cells already mentioned were present, but did not give the appearance of having the precise and regular arrangement which is seen so well in the normal skin. Besides mucous cells there was a great irregular commingling of squamous cells with variations in shape and size, also with irregularities in the size of the nucleus. In many places epithelial cells were transversely arranged running parallel with the surface. For the most part the cells forming the outer boundary of the various lobules composing the tumor were of the mucous type. (Plate III, Fig. 5).

The entire tumor after excision was fixed in 10% formalin, embedded in paraffin, sectioned serially and stained with both hematoxylin and eosin and Masson's Light Green stain. An opportunity was afforded therefore to examine in sequence the stalk-like attachment of the growth to the skin in order to determine the presence of nerve tissues.

Several small nerve trunks were found entering the growth via the narrow stalk. One of these was composed of six separate bundles of myelinated nerves, while another consisted of two nerve bundles. The enveloping connective tissue of each nerve trunk was well developed. Of particular interest was the appearance of the perineurium immediately surrounding the smaller separate groups of nerve fibers. The perineurium was conspicuous by the lamellated appearance of its cells arranged circularly in several layers (Plate IV, Figs. 7 and 8). The two primary nerve trunks which could be traced in detail entered the same lobule of the tumor at different levels by penetration of the basement membrane and were unaccompanied by blood or lymphatic vessels. On reaching the epithelium the perineural cells were still further increased in number and rested in contact with flattened adjacent epithelial cells, from which they were clearly distinguished, particularly in sections stained by the Masson technique. The lamellated arrangement of cells about the several groups of nerve fibers persisted as the nerve bundles coursed through the hyperplastic

epithelium (Plate V, Fig. 9) to reach positions near the outer surface of the tumor. Here individual nerve fibers terminated with lamellated cells still visible (Plate V, Fig. 10). Terminal modifications of nerve fibers were thus formed resembling in many respects Pacinian bodies.

In numerous areas of the growth considerable oedema was noted. This affected principally the region near the surface representing the terminal branches of the small capillaries coursing along the fibrous septa. The tips of connective tissue septa here formed a delicate reticulum in whose meshes an oedematous or albuminous material existed.

Neither necrosis nor signs of inflammation were found in the papilloma. There was no evidence that parasites were present in the abnormal tissue. No intracellular inclusion bodies could be demonstrated. Collections of monocytes with ingested particles of pigment detritus were encountered at intervals (Plate III, Fig. 6).

Summary.

The histological features of a papilloma arising in the skin of *Electrophorus electricus* (Linnaeus), containing certain terminal modifications of nerve fibers, are described, and the electrical possibilities of the regions containing palisade-like epithelial cells in the normal skin are briefly discussed.

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EXPLANATION OF THE PLATES.

Plate I.

Fig. 1. Gross specimen of lobulated papilloma excised from the skin of an electric eel, *Electrophorus electricus* (Linnaeus). Fixed in formalin.

Fig. 2. Gross specimen of papilloma, cleared in cedar oil, photographed by transillumination to show the pigmentation of the supporting stroma caused by melanophores which accompany small blood vessels. × 4.

Plate II.

Figs. 3 & 4. Photomicrographs of papilloma, composed of hyperplastic epithelium formed by commingling of squamous and mucous cells. The outer lining cells are columnar-shaped mucous cells. The supporting stroma of the papilloma is fibrous tissue containing pigment cells along the course of small blood vessels. × 65, 85.

Plate III.

Fig. 5. Mucous cells, columnar in form, covering the outer surface of the epithelial growth. × 275.

Fig. 6. Collections of monocytic cells containing ingested pigment detritus. × 325.

Plate IV.

Figs. 7 & 8. Bundles of nerve fibers with thickened lamellated perineurium lying in fibrous stroma of the growth. × 150, 250.

Plate V.

Figs. 9 & 10. Terminal modifications of nerve fibers resembling Pacinian bodies lying in the hyperplastic epithelium of the growth. × 250.

Plate VI.

Fig. 11. Normal skin of *Electrophorus electricus* (Linnaeus). Many layers of squamous epithelial cells with numerous distended mucous cells, rest upon a dense fibrous corium (**C**) containing pigment cells. Supporting the epithelium are connective tissue septa (**T**) arising from the corium and extending into the epithelium (**E**). The outer lining of the epithelium is formed by columnar shaped mucous cells. × 95.

Fig. 12. Normal epithelium of the skin of electric eel showing septa attached to which are narrow elongated epithelial cells giving a tuft-like appearance (**T**). (**C**) = corium, (**M**) = matrix cells, (**S**) = squamous cells, (**X**) = mucous cells. × 250.